# DEDARTMENT OF INTERIOR

Section: wpsC Date Measured: 10/6-7/98 Sec-Twn-Ra: Sec. 5, T. 8 Formation: Phosphoria Lat: 42 deg., 45.11' N.		WESTERN PHOSPHATE PROJECT Section: wpsD Date Measured: 6 Formation: Phosphoria Member: Meade Peak Phosphatic Shale	Page 1 of 1  \$/23-25/99 Sec-Twn-Ra: Sec. 5, T. 8 S., R. 44 E.  Lat: 42 deg., 45.07' N.  Long: 111 deg., 20.37' W.
Member: Meade Peak Phosphatic Shale  Measured By: Tysdal, Grauch, Desborough, Herring, Stillings  Notes:  eU (ppm)  Guadrangle: Upper Valley  Mine: Dry Valley	•	Measured By: Tysdal, Desborough, Herring, Grauch Notes:	Quadrangle: Upper Valley Mine: Dry Valley
DESCRIPTION  UNIT  215  Chert: It gray, in beds 2-12 in. thick; blocky. Interbedded mudstone, dk gray, hard, resistant, v siliceous; estimated that mudstone is about 10 percent of unit. Unit may		DESCRIPTION  215  Mudstone: ochre-colored.  Mudstone: dk gray; beds 1+ ft thick, st	Upper Waste
contain folded beds. Could not determine dip within this unit; used 38 degrees, as measured at 140 ft horizon; dip could be as low as 30 degrees, however. The eU measurements continued at 5 ft spacing to 310 ft above base of the section. A single composited sample was collected through the 159-310 ft interval of chert and mudstone, for	(ART)	carbonaceous films on shear planes; I of sparse, isolated nodules.  210  Phosphorite: dk gray; nodules 0.5 in. of sparse isolated nodules.	ocal 1-2 in. thick zones
which the eU values are <45 ppm.	MEMBER (P.	Mudstone: dk gray; structureless; 1 ft i	thick beds. Upper Waste
	W WEW	Mudstone: dk gray; moderately silty; b apparent bedding defined by shear pla highly fractured; fractures coated with film.	eds 1-6 in. thick; nnes? noncalcareous;
	CHER	Phosphorite: dk gray; fine grained; pel  Covered: ———BREAK IN SECT Thickness of covered interval is uncert and spoils pile at base of pit wall, but it Measured section offset about 100 ft to	DON
	A A A A A A A A A A A A A A A A A A A	basal footage (199 ft) for upper strata	The state of the s
190  Mudstone: ochre-colored, clayey; locally siliceous. Chert, it gray; forms lenses and discontinuous beds that are tectonically deformed; makes up less than 10 percent of unit.		190	
185		185	
180		180	
175		175	
170		170	
165		165	
160 Phosphorite: dk gray, weathers med gray; med grained;		160	
Mudstone: med brown; silty but not siltstone; clayey. Intervals 156-157 ft and 152-153 ft, siltstone, dk gray; finely laminated (0.04 in. thick); some (< 2 percent) phosphate pellets; blocky; resistant.		155	BER
Mudstone: It gray-brown to ochre; fairly silty; finely laminated. Secondary mica on bedding surfaces. About 1 ft above base is 3 in. thick phosphorite, med gray; oolitic.		Dolomite: gray-brown; aphanitic; abund veinlets.	Middle Waste
Chert: med gray; brecciated; radiolarians; sponge spicules(?)  Upper Waste		Mudstone: dk gray; moderate amount of sl dolomitic; beds 2-6 in. thick, resistant in. thick, alternate with less resistant be local 1 in. dia nodules, phosphatic, spa	t, in sequences 10-12 ods; structureless;
Mudstone: med brown; finely laminated; 0.04 inthick laminae; some dk gray laminae alternate with med brown laminae; clayey in zones.	MEMBER	Mudstone: dk gray; moderate amount of sl dolomitic; beds 2-6 in. thick, resistant be local 1 in. dia nodules, phosphatic, spar	t, in sequences 10-12 ods; structureless;
Phosphorite: brown, weathers silvery gray; med grained oolites and pellets; angular mud chips on some beds.  (Section offset to bench about 50 ft lower; dip changes to 38 degrees.)  Mudstone: dk brown to black-brown; very clayey; weathers  D-3 Ore	2	Mudstone: dk gray; moderate amount of sl dolomitic; beds 2-6 in. thick, resistant in. thick, alternate with less resistant be local 1 in. dia nodules, phosphatic, spai	t, in sequences 10-12 dds; structureless;
with a 0.04 inscale boxwork texture.  D-2 Ore  Phosphorite: dk gray, weathers silvery gray; finely colitic; weathers into splintery fragments; contains fine, planar, clay laminae; organic debris.		135 ————————————————————————————————————	
Phosphorite: dk brown to brown-black; mudstone; no oolites; fine 0.04 in. thick laminae; clayey; organic debris; fossils? Lower 1+ ft contains silt-rich .05 in. thick laminae.  (Beds still dip 25 degrees.)  Middle Waste		130 Mudstone: dk gray; structureless, to fine isolated, 1 in. dia nodules; beds 1-6 in.	Middle Waste
Mudstone: weathers med brown; beds 2-3 in. thick; finely laminated locally. Contains phosphatic nodules in 124-125 ft interval, and in thinner zones, locally. Fine-grained oolitic phosphatic layers, 1-3 in. thick, occur locally.		Carbon Seam: black.  Dolomite: med gray; aphanitic; beds 1-5	
120		indurated; fetid; upper part of unit is sl s	irty.
Phosphorite: weathers med gray; colitic; dense; hard; resistant; nodules, some to 1 in. across.	SHALE	Mudstone: dk gray; fairty slity, noncalca fetid; beds 2-6 in. thick; sparse mud lam thick within some beds; sparse nodular	ninae 0.04-0.1 in.
Middle Waste    Mudstone: med brown, chunky; some rock is finely   laminated; phosphatic nodules present locally; somewhat   resistant. Local, 6 in. thick phosphorite bed; med gray;   pelletal.		115	
110 Mudstone: med brown; clayey; finely laminated locally. Middle Waste		Mudstone: nodular; phosphatic?  Mudstone: dk gray; farily silty; finely lam thin, discontinuous nodular zones; pyrite	
Mudstone: dk brown, clayey. Interbeds 6-10 in. thick of lt gray, punky (altered?) dolomite. Carbonaceous, mudstone in lower part of unit.		coated with a white mineral, which cuts (marcasite?) in some rocks. Pyrite is you Carbon Seam: black.	across the pyrite unger than nodules.  Middle Waste
Dolomite: It gray, sugary; resistant; blocky; some fine laminae. Mudstone, med brown, interlayered in upper part.		Mudstone: slightly silty; slightly fetid; be hard; local, isolated, fossil fragments.  Carbon Seam: black.  Mudstone: dk gray; v little silt; finely lam	Middle Waste  Middle Waste  Middle Waste  Middle Waste
Sparse phosphatic nodules present at 95 ft interval.	ATIC	Solated, fossil fragments.   Phosphorite: dk gray; fine grained; pelle interval is well bedded; much of unit has individual pellets. This unit probably is the solution of t	s disintegrated into the "E" bed.  Middle Waste
Mudstone: weathers med brown; forms chips.  Middle Waste	H AS	Sittstone: dk gray; 1-2 in. thick beds; roc of 63-79 ft interval.	k is much like that
Phosphorite: It gray, weathers dk brown; clayey; dolomitic? contains some organic debris, phosphatic nodules.  Middle Waste	Ä	Mudstone: dk gray-brown; clay, soft.  Dolomite: grayish-brown purple; aphanit	Middle Waste
85		veinlets; rare phosphate concretions; slatectonic lens, or tectonically thickened le out 3 ft to south of line of measured sect to south.	ens, that pinches
80	1'	Mudstone: dk gray-brown; clay; altered oveinlets.  Sittstone: dk gray; structureless, with loc calcite laminae that may be concretions;	Middle Waste
Dolomite: med gray-brown; brecciated (tectonic); locally cherty. Upper 1 ft is mudstone, ochre-colored, clayey-deeply weathered dolomite(?).  Mudstone: weathers It brown; punky; some pieces may be Middle Waste		reacts with dil HCIdolomite or si calcitic thick. Thin clayey mudstone layers 1-2 is siltstone beds contain many phosphatic 0.25-1 in. dia; siltstone contains mudston thick.	c; beds 4-8 in. in. thick between concretion/pebbles
weathered dolomite. Upper 2 ft grades into overlying unit.		70  Siltstone: dk gray; structureless; two thic (dolomitic?). Local 1 in. dia concretions.  Siltstone: dk gray; structureless, with loc calcite laminae that may be concretions;	al 0.05-0.4 in. thick Middle Waste
65 Chert: silicified dolomite? vellowish brown; tectonically Middle Waste	PEAK	reacts with dil HCI-dolomite or slightly of thick. Thin clayey mudstone layers 1-2 is sittstone beds contain many phosphatic 0.25-1 in. dia; non-structureless siltstone laminae 0.5-1 in. thick.	n. thick between concretion/pebbles
brecciated; resistant.  Mudstone: It brown to tan to v It gray, interlaminae; sl calcareous; some beds are punky. Most beds have a flaky texture. Fe- and Mn-oxides; minor carbonate and silicate		Dolomite: dk gray; aphanitic; sl fetid; veir beds about 6 in. thick; 2-5 in. dia noduler black shiny slickensides on fracture surfa	s-phosphatic? aces.  Middle Waste
veinlets (secondary). Upper half is more clayey and contains dark, orgainc material. One 6 in. thick "cherty" (secondary) bed; forms chips.  Carbon Seam: black; deeply weathered.  Middle Waste		dark gray mud laminae; 6 in. thick bed of aphanitic, in middle. Lower part has 1 in concretions.	. dia carbonate
Phosphorite: weathers med gray; fine-grained colites, rounded to faceted, angular.  Middle Waste  Mudstone: gray-brown; clayey; contains several 1-2 in. thick phosphatic colite layers; some fine laminae. Local Fe or		calcite and milky tan calcite veinlets; pos concretions; shiny black slickensides alo Sittstone: dk gray; fine grained, v calcare laminae; local phosphate laminae; well b	sible sulfide and fractures.  Middle Waste Solution in the sulfide
Mn coatings.		Calcite veins, increase toward top of unit  Mudstone: dk gray; generally finely lamir It gray 0.04-0.1 in. thick calcite laminae; a nodules. Forms beds 2-6 in. thick; well b	mated, but contains some calcitic edded. Middle Waste
45  Phosphorite: weathers med gray; fine-grained colites.  Middle Waste  Mudstone: It brown to ochre; very clayey; sl calcareous.  Middle Waste	MEADE	Mudstone: dk gray; generally finely lamin lt gray 0.04-0.1 in. thick calcite laminae; a nodules. Forms beds 2-6 in. thick; well be some small granules.	some calcitic edded.
Mudstone: gray-brown, sl calcareous, sl micaceous; interbeds of ochre-colored clayey beds 0.5-4 in. thick; upper 1 ft is fine grained; oolitic; phosphatic.  C-Bed  Phosphorite: dk brown; finely oolitic; clayey; contains abundant clay; dk gray Fe-oxide (Mn-oxide?) coatings that	2	Phosphorite: dk gray; dine grained; peller poorty indurated; altered(?).  Dolomite: med brown; aphanitic; sl fetid; laminae locally; fracture surfaces coated	faint horizontal with calcite and
abundant clay, dx gray Peoxide (Wil-oxide) Court across layering.  Mudstone: med brown; micaceous; sparse dk brown organic flecks; some fine- to v fine grained oolites; clayey; finely laminated-0.05 in. thick laminae.		unknown yellow rosettes. Near middle is organic-rich mudstone.  Mudstone: dk gray; moderate silt; structu sl fetid; beds 1-2 in. thick; carbonate vein with black, yellow, green oxides; forms bl	False Cap reless; organic-rich, s; joints coated False Cap
Phosphorite: dk gray, weathers med gray; forms 0.5 insize chips; fine-grained colites; uniform grain size. Contains modern rootlets.  B-Mudstone  Lower B Ore		Dolomite: dk gray; aphanitic; fetid; 1 in. the contains many thin calcite veinlets; forms  Dolomite: pale yellowish brown, weathers fetid; surfaces coated with yellow-white fi	s chips.  False Cap  Upper B Ore
Phosphorite: dk gray, weathers it gray; weathers into 0.5 insize pieces; fine-grained colites, well rounded to angular (due to deformation?); some laminae within pieces; dense.  A-Cap  Mudstone: weathers med gray-brown; contains it brown to		Phosphorite: dk gray; beds 1-4 in. thick; s  Phosphorite: dk gray; pelletal; weathers it  Limestone: dk gray; v fine grained, silty; s	nto single pellets.  B Mudstone
25 tan 0.2-0.4 in. thick laminae. Some "rock" is sI calcareous.  Basal and upper 1 ft contains deformed fine-grained phosphatic colites with argillaceous laminae; weathers rubbly.		strongly fetid; beds to 6 in. thick; very har beds about 6 in. thick; 2-5 in. dia nodules black shiny slickensides on fracture surface.	rd. Lower B Ore reined with calcite;phosphatic? ces.
Phosphorite: weathers med gray; fine-grained well rounded oolites and faceted angular "colites" or pellets. Weathers into chips and thumb-size pieces. Tan coatings on and between colites.		Dolomite: manganese stain. Bed probab of A Cap.  Dolomite: med gray; v fine grained; fetid; brown, contain rounded mud granules; w to It brown; beds 2-4 in. thick; .05-0.1 in. t	some beds are med eathers along joints
15		to it brown; beds 2-4 in. thick; .05-0.1 in. 1 weathered beds; some joints coated with phosphorite; carbonaceous fossil plant(?) some bed surfaces; some beds much mo others.  Phosphorite: fine pellets to granule-size; in thick; .05-0.1 in. 1 weathered beds; some joints coated with phosphorite; carbonaceous fossil plant(?)	calcite; sparse impressions on ore weathered than  A-Bed Ore
Mudstone: pale brown to tan, weathered color; micaceous; silt grains, probably quartz; noncalcareous. Organic specks are present, probably modern; Fe- or Mn-oxide coatings present on some grains.  Covered: Footwall mudstone. Thickness is from oral.		Phosphorite: fine pellets to granule-size; replaced by phosphate and calcite.  Phosphorite: dk gray; pelletal, fine grainer small chips and individual pellets.  Mudstone: dk brown; "Red Mudstone" of	d; weathers into Footwall Mudstone
Covered: Footwall mudstone. Thickness is from oral communication with FMC geologist. Dip for lower part of measured section is from Grandeur Tongue (Park City Formation) that underlies unit, exposed in dozer cut about 200 ft to south of section.		Mudstone: dk brown; "Red Mudstone" of useage.  Dolomite: med brown, weathers it brown; in. thick.  Covered	Footwall Mudstone
	DATUMBASE OF FISH-SCALE BED	Covered  Phosphorite: med gray; speckled white; p	

### INTRODUCTION

The U.S. Geological Survey (USGS) has studied the Permian Phosphoria Formation in southeastern Idaho and the entire Western U.S. Phosphate Field throughout much of the twentieth century. In response to a request by the U.S. Bureau of Land Management, a new series of resource, geological, and geoenvironmental studies was undertaken by the USGS in 1998. To accomplish these studies, the USGS has formed cooperative research relationships with two Federal agencies, the Bureau of Land Management and the U.S. Forest Service, tasked with land management and resource conservation on public lands; and with five private companies currently leasing or developing phosphate resources in southeastern Idaho. The companies are Agrium U.S. Inc. (Rasmussen Ridge mine), FMC Corporation (Dry Valley mine), Rhodia Inc. (Wooley Valley mine—inactive), J.R. Simplot Company (Smoky Canyon mine), and Solutia Inc. (Enoch Valley mine). Some of the mineralogical research associated with this project is supported through a cooperative agreement with the Department of Geology and Geological Engineering, University of Idaho. Present studies consist of integrated, multidisciplinary research directed toward (1) resource and reserve estimations of phosphate in selected 7.5-minute quadrangles; (2) elemental residence, mineralogical and petrochemical characteristics; (3) mobilization and reaction pathways, transport, and fate of potentially toxic elements associated with the occurrence, development, and societal use of phosphate; (4) geophysical signatures; and (5) improving the understanding of deposit origin. Because raw data acquired during the project will require time to interpret, the data are released in open-file reports for prompt availability to other workers. Open-file reports associated with this series of studies are submitted to each of the Federal and industry cooperators for technical review; however, the USGS is solely responsible for the data contained in the reports.

#### **MEASURED SECTIONS**

Stratigraphic sections of the Phosphoria Formation were measured and sampled by the USGS at several places in southeastern Idaho. The sections, generally lacking interpretation and explanatory notes, are published as preliminary reports as they are assembled. No thin section, X-ray, or analytical technique other than gamma-ray spectrometry has been used to augment the field descriptions of the rock units in this report. The descriptions are accompanied by a computer-generated lithologic log. Informal bed names used at the Dry Valley mine are shown in the unit column. Contacts of units within the ore zones were picked by mine personnel; those within the middle and upper waste zones generally were picked by USGS personnel. The units within the measured sections were sampled for geochemical and petrological analysis and also were evaluated with a variety of geophysical techniques. English units of measurement are used throughout this report to facilitate direct correspondence with units in the extensive historical literature on the Phosphoria and with current industry usage.

The Phosphoria Formation in the vicinity of the measured sections consists of three members, which in ascending order are the Meade Peak Phosphatic Shale, the Rex Chert, and the informally named cherty shale (McKelvey and others, 1959; Hale, 1967; Rioux and others, 1975). The measured sections of this report focus on the Meade Peak Phosphatic Shale Member. The Meade Peak unconformably overlies the Grandeur Tongue of the Permian Park City Formation, and the cherty shale member is overlain by the Triassic Dinwoody Formation. Both sections were measured at essentially the same geographic position, but section wpsC (western phosphate section C) was of rock about 150 ft higher in elevation than that of section wpsD, and much closer to the land surface that existed just prior to mining. Measuring a pair of sections close together, but at different depths below this land surface, permits evaluation of important effects of weathering on rock geochemistry. Measurements record true thickness. Adjustments were made for dip of beds at the time of measurement. Except for upper waste strata of wpsD, the two sections were measured on horizontal surfaces exposed by mining equipment. The two sections are of similar thickness, as expected. The upper ore zone of section wpsD was not exposed on the floor of the open-pit mine because it was mostly covered by talus and waste-pile debris at the base of the pit wall. Waste above the upper ore zone of wpsD was measured on the

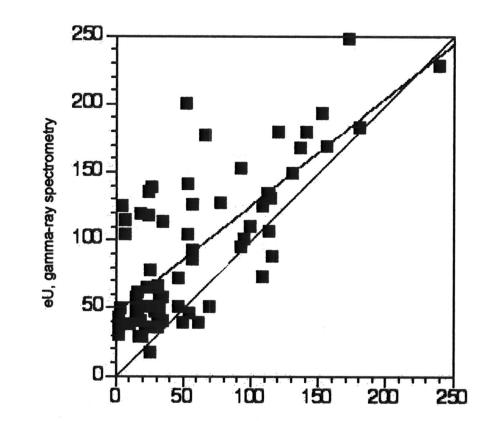
#### **EQUIVALENT URANIUM (eU)**

Each of the two sections is accompanied by a profile of the equivalent uranium (eU) measurements taken with a gamma-ray spectrometer. Concentrations of eU are given in parts per million (ppm). Section wpsC was measured with an Exploranium GR-320 and section wpsD was measured with a GAD-6. These instruments measure gross gamma-ray flux (including cosmic rays) and provide a quantitative measure of K, U, and Th. Determination of the abundance of U and Th occurs via detection and counting of gamma rays of specific energy associated with a particular daughter radionuclide for each element, <sup>214</sup>Bi with a 1.76 MeV (million electron volt) gamma-ray in the case of uranium. Calculation of total abundance of U and Th assumes secular equilibrium between the measured daughter nuclide and the parent isotope and all intermediate daughter nuclides for each individual element. Potassium abundance is determined from the measurement of gamma rays associated with the decay of  $^{40}$ K. The spectrometer integrates detection over a  $2\pi$ geometry of approximately 1/2 m<sup>3</sup> and has proportionally higher detection sensitivity to those gamma rays that are emitted closer to the detector. The calibration equations for the two spectrometers assume this geometry on a planar surface and are based on analysis of concrete pads of known composition of the three elements. The calibration coefficients, as well as the constants for subtracted background counts, are a function of latitude, altitude, rock density, and moisture. The coefficients become less reliable as location and rock conditions change from those of the calibration.

In Tysdal and others (1999), we plotted eU concentration data after normalization of the highest eU concentration of section wpsA, 373 ppm, to 200 ppm and of section wpsB from a high of 468 ppm to a scaled high value of 282 ppm. For the eU data graphed in Tysdal and others (1999), the original eU measurement can be extracted from the plotted values by multiplying by scaling factors of 1.87 for section wpsA and 1.66 for section wpsB. This scaling was done because published reports from the 1970's and earlier on uranium and eU concentrations in the Meade Peak Phosphatic Shale Member state that few uranium concentrations from this member exceed 200 ppm (see Swanson, 1970, and references therein) and we had little independent check on accuracy of the spectrometer data. However, new analytical data as part of our study question these past published relationships.

Recently, we re-analyzed a subset of samples using delayed neutron (DN) analysis, which has a precision of better than 3 percent and an accuracy of generally better than 5 percent (McKown and Millard, 1987). The relationship between the two measurement techniques is shown in figure 1 for 70 samples. The DN analysis can be used to assess the uranium concentration data in Herring and others (1999), which were obtained using inductively-coupled plasma atomic emission spectroscopy (ICP-AES) measurements with a lower detection limit of 100 ppm. For a common set of 12 samples where ICP-AES measurements indicate uranium concentrations greater than the detection limit of 100 ppm, the DN analysis shows that ICP-AES measurements average 12 percent greater than those of DN and have a relative standard deviation of 12 percent. Given this relative credibility in the ICP-AES technique as verified by DN analysis, the frequency of uranium concentrations >100 ppm among the set of all composited stratigraphic samples of the Meade Peak consequently can be estimated. For 182 channel samples from sections wpsA, wpsB, wpsC, and wpsD as measured by ICP-AES, 18 percent of the uranium concentrations are >100 ppm, 16 percent are between 100 and 200 ppm, and 2 percent are >200 ppm. These channel samples average concentrations over intervals from 1 to 15 feet of true stratigraphic thickness. Clearly, each channel sample will have some uranium concentrations that are indeed higher, perhaps considerably so, than the interval average. Consequently, we believe that uranium concentrations in excess of 200 ppm are not as uncommon as reported by Swanson (1970, and references therein) and that uranium concentration measurements from the gamma-ray spectrometers are reasonably correct and should be reported as measured rather than scaling them against an assumed upper limit value.

Previous studies of the Phosphoria Formation maintain that there is a consistent relationship between eU and total uranium contents and between total uranium and phosphate contents (McKelvey, 1956). Our measurements indicate considerable scatter in both relationships (fig. 1; Herring and others, 1999; Herring, unpub. data). Measured eU concentrations, even between adjoining 1 foot intervals of consistent lithologic character, often exhibit considerable variability. We expect that this results from: (1) fine-scale variability in the concentration of uranium; (2) the effect of the geometry of the dipping rocks; or (3) from lack of secular equilibrium. Scatter in the U to P<sub>2</sub>O<sub>5</sub> relationship results from uranium removal or addition by syndepositional effects and (or) by post-depositional alteration, especially weathering. The uranium is mostly located in the phosphate mineral lattice as a substitute for Ca; location of the decay (daughter) products is uncertain. For the phosphatic rocks of the Phosphoria Formation, total gamma counts are dominated by decay of uranium and its various daughter products. K2O is generally <1 percent in the phosphorite and <3 percent in the middle waste shale; Th concentrations are generally <15 ppm in ore and waste shale (Altschuler and others, 1958; Swanson, 1970; Herring and others, 1999; Herring, unpub. data).



U, ppm, delayed neutron, channel samples

Figure 1. Comparison of measured uranium concentration by delayed neutron analysis in channel samples with gamma-ray spectroscopy measurements taken at 1-foot truethickness stations through the same intervals and arithmetically averaged. The 1:1 and least-squares regression ( $R^2 = 0.55$ ) lines are shown.

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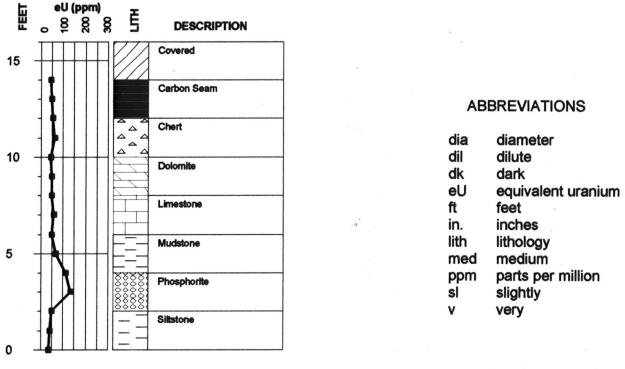
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The sections were measured within the Dry Valley mine, operated by the FMC Corporation. We thank FMC for providing access and we thank company personnel who freely discussed the geology of the area.

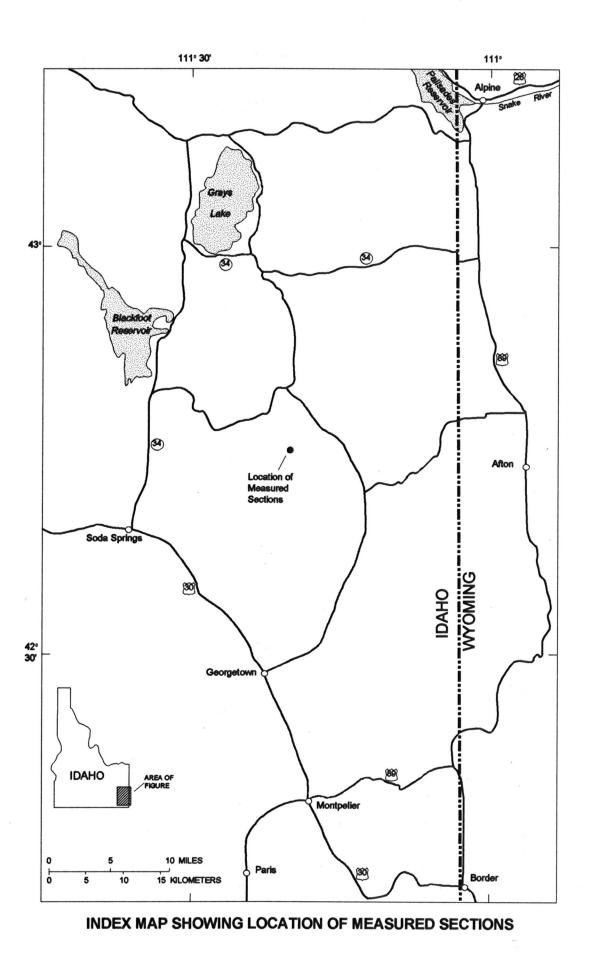
**ACKNOWLEDGMENTS** 

## **EXPLANATION**



# CONVERSIONS

Some thin layers within the stratigraphic sections originally were measured in millimeters. then converted to English units. A thickness of 1 millimeter converts to 0.04 inches, implying a measurement precision greater than actually exists.



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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards. Any use of trade, product, or firm names is for descriptive purposes only and does not imply an endorsement by the U.S. Government.

STRATIGRAPHIC SECTIONS AND EQUIVALENT URANIUM (eU), MEADE PEAK PHOSPHATIC SHALE MEMBER OF PERMIAN PHOSPHORIA FORMATION, DRY VALLEY, CARIBOU COUNTY, IDAHO